Chapter 13 - Energy sources

Fossil fuels

What is a fuel?

How are fossil fuels used?

Alternative sources of energy

Nuclear power
Hydroelectric power
Geothermal energy
Wave power
Tidal power
Wind power
Solar energy
Biomass and biogas

Chemical energy

Combustion
Enthalpy of neutralisation (molar heat of neutralisation)

Change of state

Cells and batteries

Fuel cells

Checklist

Additional questions

Fossil fuels

Coal, oil and natural gas are all examples of **fossil fuels**. The term, fossil fuels, is derived from the fact that they are formed from dead plants and animals which were fossilised over 200 million years ago during the carboniferous era.

Coal was produced by the action of pressure and heat on dead wood from ancient forests which once grew in the swampland in many parts of the world under the prevailing weather conditions of that time. When dead trees fell into the swamps they were buried by mud. This prevented aerobic decay (which takes place in the presence of oxygen). Over millions of years, due to movement of the Earth's crust (Chapter 17) as well as to changes in climate, the land sank and the decaying wood became covered by even more layers of mud and sand. Anaerobic decay (which takes place in the absence of oxygen) occurred, and as time passed the gradually forming coal became more and more compressed as other material was laid down above it (Figure 13.1). Over millions of years, as the layers of forming coal were pushed deeper and the pressure and temperature increased, the final conversion to coal took place (Figure 13.2).

Different types of coal were formed as a result of different pressures being applied during its formation. For example, anthracite is a hard coal with a high carbon content, typical of coal produced at greater depths. Table 13.1 shows some of the different types of coal along with their carbon contents.

Oil and gas were formed during the same period as coal. It is believed that oil and gas were formed from the remains of plants, animals and bacteria that once lived in seas and lakes. This material sank to the bottom of these seas and lakes and became covered in mud, sand and silt which thickened with time.

Figure 13.1 Piece of coal showing a fossilised leaf.

Figure 13.2 Cutting of coal is extremely mechanised.

Table 13.1 The different coal types.

Type of coal	Carbon content/%
Anthracite	90
Bituminous coal	60
Lignite	40
Peat	20

Anaerobic decay took place, and, as the mud layers built up, high temperatures and pressures were created which converted the material slowly into oil and gas. As rock formed, earth movements caused it to buckle and split, and the oil and gas were trapped in folds beneath layers of non-porous rock or cap-rock (Figures 13.3 and 13.4).

Figure 13.3 Oil production in the North Sea.

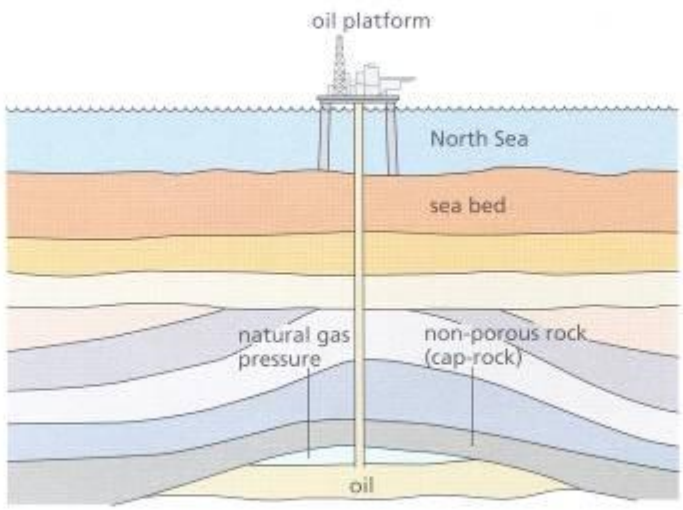


Figure 13.4 Natural gas and oil are trapped under non-porous rock.

Questions

1. Coal, oil and natural gas are all termed 'fossil fuels'. Why is the word 'fossil' used in this context?

2a. Name the process by which plants convert carbon dioxide and water into glucose.

b. What conditions are necessary for this process to occur?

3. Draw a flow diagram to represent the formation of coal, oil or gas.

What is a fuel?

A fuel is a substance which can be conveniently used as a source of energy. Fossil fuels produce energy when they undergo **combustion**.

fossil fuel + oxygen → carbon dioxide + water + energy

For example, natural gas burns readily in air (Chapter 12).

methane + oxygen → carbon dioxide + water + energy

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

It should be noted that natural gas, like crude oil, is a mixture of hydrocarbons such as methane, ethane and propane, and may also contain some sulphur. The sulphur content varies from source to source (Chapter 16). Natural gas obtained from the North Sea is quite low in sulphur.

The perfect fuel would be:

- cheap
- available in large quantities
- safe to store and transport
- easy to ignite and burn, causing no pollution
- capable of releasing large amounts of energy.

Solid fuels are safer than volatile liquid fuels like petrol and gaseous fuels like natural gas.

How are fossil fuels used?

A major use of fossil fuels is in the production of electricity. Coal, oil and natural gas are burned in power stations (Figure 13.5) to heat water to produce steam, which is then used to drive large turbines (Figure 13.6). At least 80% of the electricity generated in the UK is generated using fossil fuels. However, it should be noted that the relative importance of the three major fossil fuels is changing. Coal and oil are becoming less important while natural gas is increasingly important.

Figure 13.5 A power station.

In a power station, the turbine drives a generator to produce electricity which is then fed into the National Grid (Figure 13.6). The National Grid is a system for distributing electricity throughout the country.

Other major uses of the fossil fuels are:

- as a major feedstock (raw material) for the chemicals and pharmaceuticals industries
- for domestic and industrial heating and cooking
- as fuels for various forms of vehicle transport.

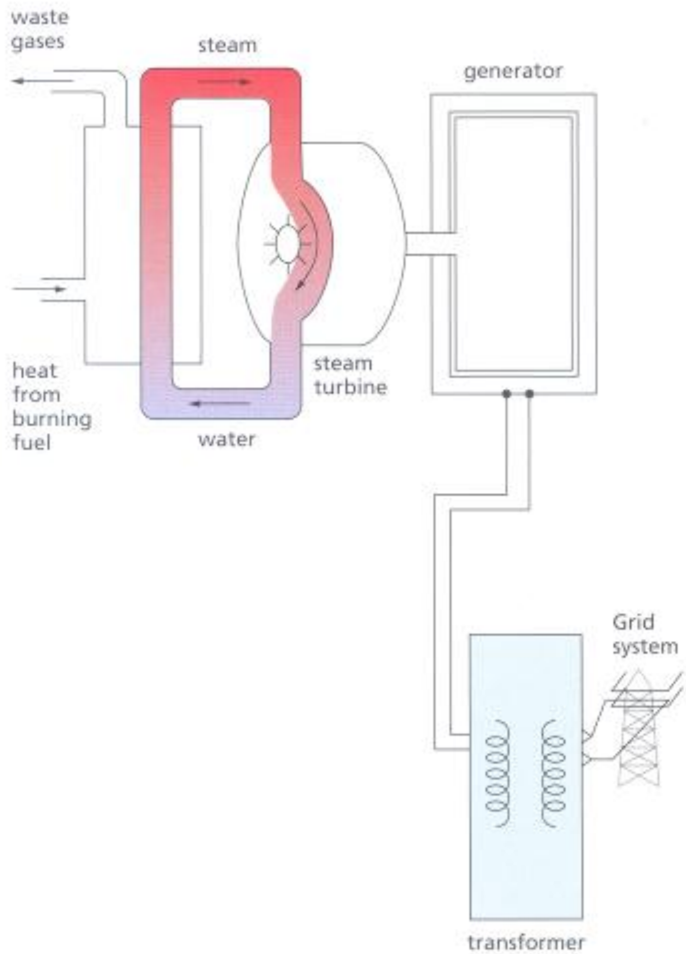


Figure 13.6 The way in which fuels are used to produce electricity.

Questions

1. 'We have not yet found the perfect fuel.' Discuss this statement.

2. 'Fossil fuels are a major feedstock for the chemical and pharmaceutical industries.' With reference to Chapter 12, give examples which support this statement.

Alternative sources of energy

Fossil fuels are an example of **non-renewable** resources, so called because they are not being replaced at the same rate as they are being used up. For example, we have approximately 55 years' supply of crude oil remaining from known reserves if we continue to use it at the current rate as a source of energy and chemicals (Table 13.2). It is important to use non-renewable fuels carefully and to consider alternative, **renewable** sources of energy for use in the future.

Table 13.2 Estimates of how long our fossil fuels will last.

Fossil fuel	Estimated date it is expected to run out
Gas	2045
Oil	2055
Coal	2500

Nuclear power

Calder Hall power station in Cumbria, on the site of the present-day nuclear power complex at Sellafield (Figure 13.7), opened in 1956 and was the first nuclear reactor in the world to produce electricity on an industrial scale.

Figure 13.7 The nuclear power complex at Sellafield, Cumbria.

Nuclear reactors harness the energy from the fission of uranium-235.

Nuclear fission occurs when the unstable nucleus of a radioactive isotope splits up, forming smaller atoms and producing a large amount of energy as a result. Scientists believe that the energy comes from the conversion of some of the mass of the isotope.

This fission process begins when a neutron hits an atom of uranium-235, causing it to split and produce three further neutrons. These three neutrons split three more atoms of uranium-235, which produces nine neutrons and so on. This initiates a **chain reaction** (Figure 13.8).

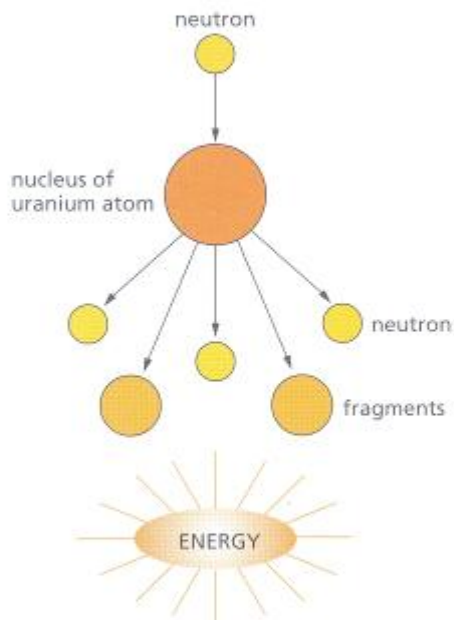


Figure 13.8 Chain reaction in uranium-235 fission.

In a reactor the fission process cannot be allowed to get out of control as it does in an atomic bomb. To prevent this, boron control rods can be pushed into different positions in the reactor to absorb some of the neutrons which are produced and so slow down the chain reaction. If this is done, the energy released from the reaction is obtained in a more controlled way. The energy is used to produce steam, which in turn is used to generate electricity (Figure 13.6).

However, there are problems. The main problem associated with a nuclear power station is that the reactor produces highly radioactive waste materials. These waste materials are difficult to store and cannot be disposed of very easily. Also, leaks of radioactive material have occurred at various sites throughout the world. Accidents at a small number of nuclear

power stations, such as Chernobyl in the Ukraine (Figure 13.9) and Three Mile Island in the US, have led to a great deal of concern about their safety. In the UK the safety record of the nuclear power industry is relatively good because it is subject to strict controls.

Figure 13.9 A nuclear accident happened at the Chernobyl power station in 1986.

Hydroelectric power

Hydroelectric power (HEP) is electricity generated from the energy of falling water (Figure 13.10). It is an excellent energy source and electricity has been generated in this way in the mountainous areas of Scotland and Wales for some time. It is a very cheap source of electricity. Once you have built the power station, the energy is absolutely free. In some mountainous areas of the world, such as the Alps, HEP is the main source of electricity. One of the main advantages of this system is that it can be quickly used to supplement the National Grid at times of high demand. A disadvantage of HEP schemes is that they often require valleys to be flooded and communities to be moved.

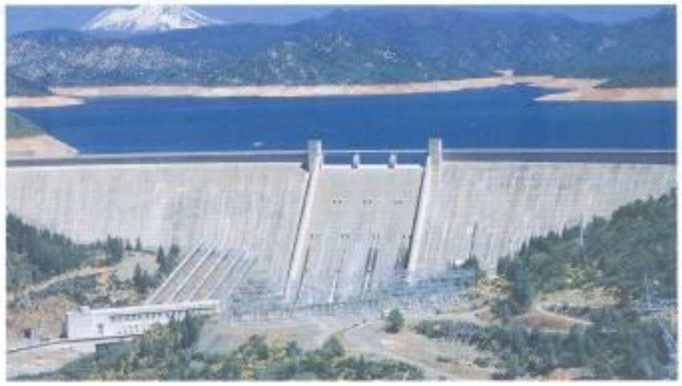


Figure 13.10 A hydroelectric power station.

Geothermal energy

Water is pumped into hot rocks in the Earth's crust far below ground level (Figure 13.11). The internal heat of the rocks converts the water to steam, which is used to drive turbines and hence generate electricity. This is a major source of electrical energy in Iceland.

Geothermal energy is a natural, non-polluting source of energy. Experiments on the viability of geothermal energy have been conducted in Cornwall.

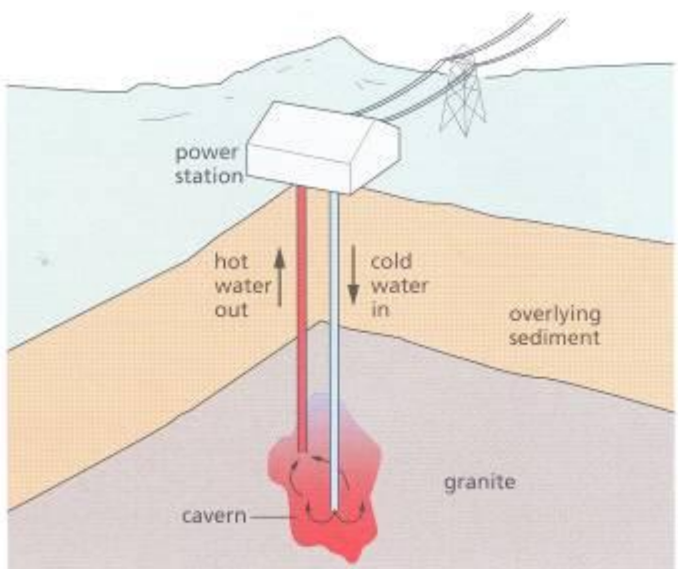


Figure 13.11 Geothermal plant.

Wave power

In this method the energy of moving waves is used to generate electricity. Figure 13.12 shows the Salters' 'Duck' wave machine in operation. The vertical motion of the waves is converted to rotary motion, which is used to drive a generator producing electricity. A disadvantage of this method for generating large amounts of electricity is that vast numbers of strings of these ducks would be required.

Wave power is a non-polluting source of energy.

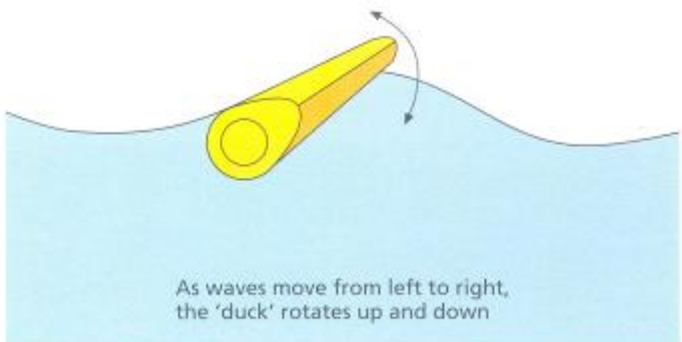


Figure 13.12 The Salters' 'Duck' wave machine.

Tidal power

The ebb and flow of the tides drives turbines built into a dam or barrage across an estuary where the height difference between high and low tides is large (Figure 13.13). There is a successful tidal power station across the River Rance near St Maio in northern France. The most likely place in Britain to put a tidal barrage is across the Severn Estuary near Bristol, but there would be environmental disadvantages with such a scheme. For example, there would be a threat to the wildlife around the estuary, since the mud banks are one of the few remaining sites in Britain for wildfowl and wading birds to nest.

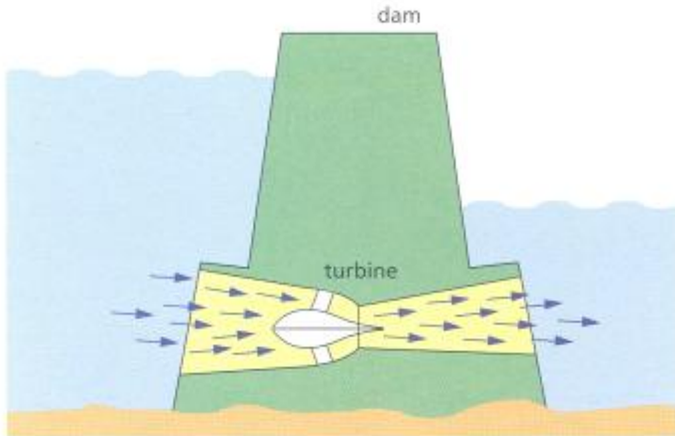


Figure 13.13 Tidal power – the ebb and flow of the tide drives the turbine set into the barrage or dam.

Wind power

This method uses the force of the wind to turn generators to produce electricity. Wind machines 24 m high are capable of generating 200 kW of electricity per machine. Large 'wind farms' have been developed in many parts of the world, for example in the US and on the Pennines in England (Figure 13.14).

The disadvantages of wind power are that the wind farms are somewhat unsightly, they require vast amounts of land, as the machines have to be carefully arranged so that their operation is not impaired, and they produce a lot of noise.

Figure 13.14 Wind farm at Ovenden Moor, Yorkshire.

Solar energy

Two possible methods exist to use the energy of the Sun. In the first, the Sun's energy can be absorbed on to black-painted collector plates and used to heat water and homes (Figure 13.15). This method is relatively cheap. The second method involves the use of photovoltaic cells or photocells to generate electricity (Figure 13.16). Disadvantages include the initial cost of cells as well as the fact that the Sun does not shine all the time. To solve this problem, solar cells are commonly linked to storage batteries.

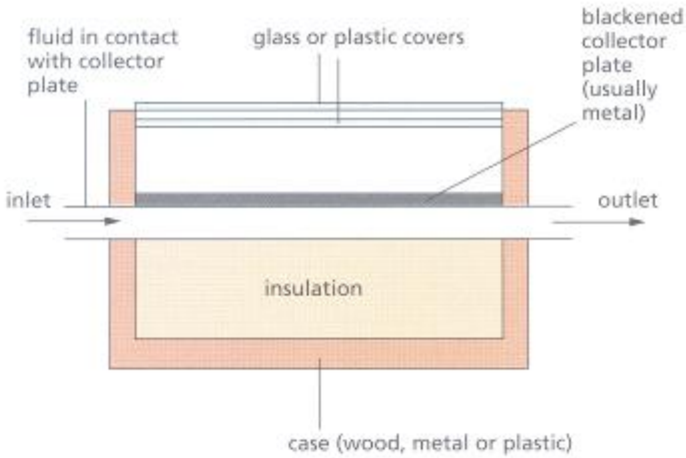


Figure 13.15 A single solar energy panel.

Figure 13.16 A bank of photocells.

Biomass and biogas

When any biological material, whether plant or animal, is converted into energy, this energy is called **biomass** energy. It can be taken from animal or plant materials in different ways:

- by burning it, for example wood (Figure 13.17)
- by pressing out oils that can be burned
- by fermenting it to produce fuels such as ethanol or methane.

Figure 13.17 Biomass energy is produced by burning wood.

At least 50% of the world's population rely on wood as their main energy source.

In India there are millions of methane generators. Methane generated by the digestion of animal waste is called **biogas**. The biogas produced is used for cooking, heating and lighting. The by-product of this process is an excellent fertiliser.

Some countries have already experimented with ethanol as a fuel for cars. Up to 20% of ethanol can be added to petrol without the need to adjust the carburettor. Brazil, which has few oil reserves, produces ethanol by fermentation (breakdown by enzymes) of sugar cane and grain, and uses it as a petrol additive (Figure 13.18). The Brazilian government has cut down its petrol imports by up to 60% through using this alcohol/petrol mixture.

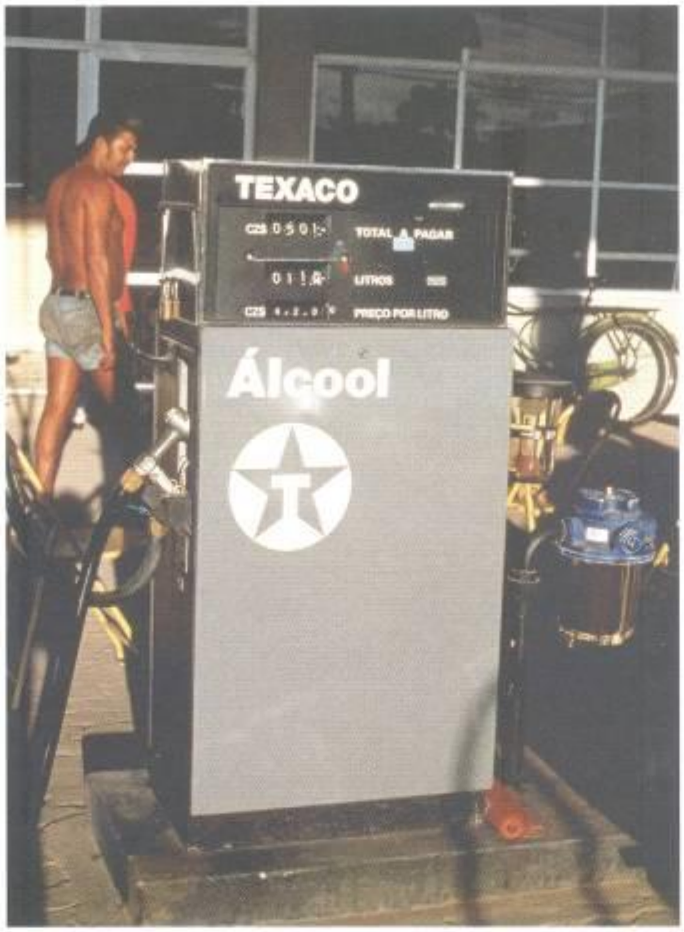


Figure 13.18 In Brazil cars use an ethanol/petrol mixture.

Questions

1. Draw up a table showing the alternative sources of energy along with their advantages and disadvantages.

2. What is meant by the terms:

a. non-renewable energy sources?
b. renewable energy sources?

Chemical energy

We obtain our energy needs from the combustion of fuels, such as hydrocarbons, from the combustion of foods and from many other chemical reactions.

Combustion

When natural gas burns in a plentiful supply of air it produces a large amount of energy.

methane + oxygen $\rightarrow$ carbon dioxide + water + heat energy

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) + \text{heat energy}$$

During this process, the **complete combustion** of methane, heat is given out. It is an **exothermic** reaction. If only a limited supply of air is available then the reaction is not as exothermic and the poisonous gas carbon monoxide is produced.

methane + oxygen $\rightarrow$ carbon monoxide + water + heat energy

$$2CH_4(g) + 3O_2(g) \rightarrow 2CO(g) + 4H_2O(l) + \text{heat energy}$$

This process is known as the **incomplete combustion** of methane.

The energy changes that take place during a chemical reaction can be shown by an energy level diagram. Figure 13.19 shows the energy level diagram for the complete combustion of methane.

When any reaction occurs, the chemical bonds in the reactants have to be broken - this requires energy. When the new bonds in the products are formed, energy is given out (Figure 13.20). The **bond energy** is defined as the amount of energy in kilojoules (kJ) associated with the breaking or making of one mole of chemical bonds in a molecular element or compound.

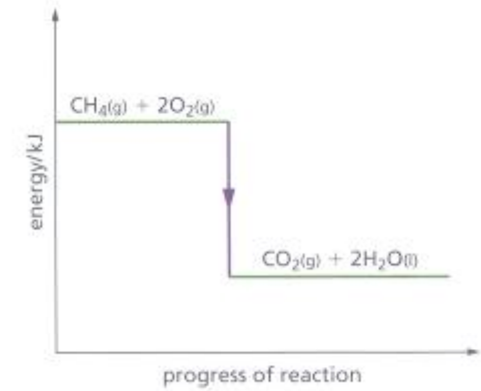


Figure 13.19 Energy level diagram for the complete combustion of methane.

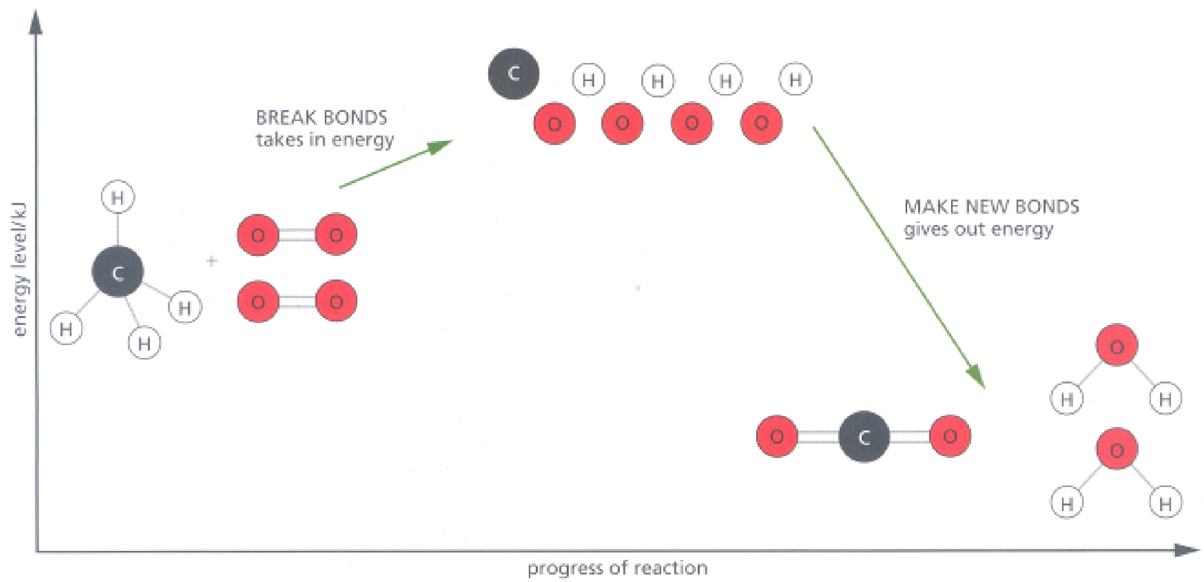


Figure 13.20 Breaking and forming bonds during the combustion of methane.

Using the bond energy data from Table 13.3, which tells us how much energy is needed to break a chemical bond and how much is given out when it forms, we can calculate how much energy is involved in each stage.

Bond breaking

Breaking 4 C—H bonds in methane requires

$4 \times 435 = 1740$ kJ

Breaking 2 O=O bonds in oxygen requires

2 × 497 = 994 kJ

Total = 2734 kJ of energy

Table 13.3 Bond energy data.

Bond	**Bond energy (kJ mol^{-1})**
C—H	435
O=O	497
C=O	803
H—O	464
C—C	347
C—O	358

Making bonds

Making 2 C=O bonds in carbon dioxide gives out

2 × 803 = 1606 kJ

Making 4 O—H bonds in water gives out

4 × 464 = 1856 kJ

Total = 3462 kJ of energy

Energy difference

= energy required - energy given out when to break bondsbonds are made

= 2734 - 3462

= -728 kJ

The negative sign shows that the chemicals are losing energy to the surroundings, that is, it is an exothermic reaction. A positive sign would indicate that the chemicals are gaining energy from the surroundings. This type of reaction is called an **endothermic** reaction.

The energy stored in the bonds is called the **enthalpy** and is given the

symbol H. The change in energy going from reactants to products is called the **change in enthalpy** and is shown as ΔH (pronounced 'delta H'). ΔH is called the heat of reaction.

For an exothermic reaction ΔH is negative and for an endothermic reaction ΔH is positive.

When fuels, such as methane, are burned they require energy to start the chemical reaction. This is known as the **activation energy, E_A** (Figure 13.21).

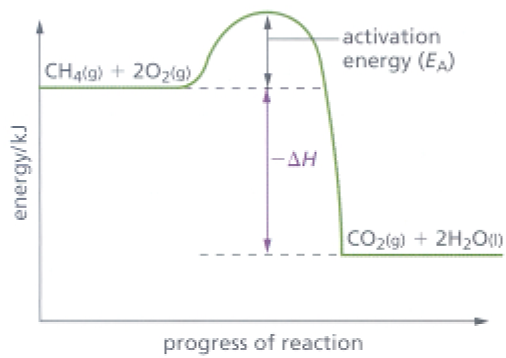


Figure 13.21 Energy level diagram for methane/oxygen.

In the case of methane reacting with oxygen, it is the energy involved in the initial bond breaking (Figure 13.20). The value of the activation energy will vary from fuel to fuel.

Endothermic reactions are much less common than exothermic ones. In this type of reaction energy is absorbed from the surroundings so that the energy of the products is greater than that of the reactants. The reaction between nitrogen and oxygen gases is endothermic (Figure 13.22).

nitrogen + oxygen → nitrogen (II) oxide

$$N_2(s) + O_2(g) \rightarrow 2NO(g)$$

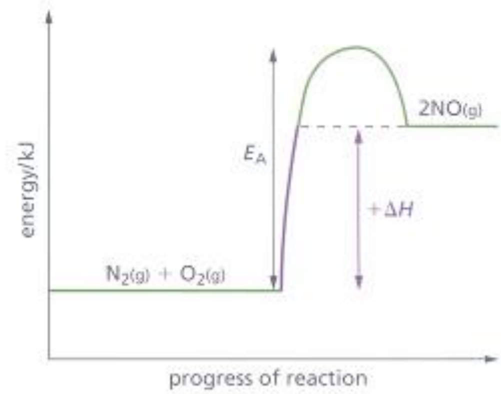


Figure 13.22 Energy level diagram for nitrogen/oxygen.

Dissolving is often an endothermic process. For ex-ample, when ammonium nitrate dissolves in water the temperature of the water falls, indicating that energy is being taken from the surroundings. Photosynthesis and thermal decomposition are other examples of endothermic processes.

In equations it is usual to express the ΔH value in units of kJ mol^{-1}. For example:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) \quad \Delta H = 728 \text{ kJ mol}^{-1}$$

This ΔH value tells us that when 1 mole of methane is burned in oxygen, 728 kJ of energy are released. This value is called the **enthalpy of combustion** of methane (or **molar heat of combustion** of methane).

Enthalpy of neutralisation (molar heat of neutralisation)

This is the enthalpy change that takes place when 1 mol of hydrogen ions (H^+(aq)) is neutralised.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l) \quad \Delta H = -57 \text{ kJ mol}^{-1}$$

This process occurs in the titration of an alkali by an acid to produce a neutral solution (Chapter 7).

Questions

1. Using the bond energy data given in Table 13.3:

a. Calculate the enthalpy of combustion of ethanol, a fuel added to petrol in some countries.

b. Draw an energy level diagram to represent this combustion process.

c. How does this compare with the enthalpy of combustion of heptane (C_7H_{14}), a major component of petrol, of -4853 kJ mol^{-1}?

d. How much energy is released per gram of ethanol and heptane burned.

2. How much energy is released if:

a. 0.5 mole of methane is burned?

b. 5 moles of methane are burned?

c. 4 g of methane are burned?

(A_r:C = 12, H = 1)

3. How much energy is released if:

a. 2 moles of hydrogen ions are neutralised?

b. 0.25 mole of hydrogen ions is neutralised?

c. 1 mole of sulphuric acid is completely neutralised?

Change of state

In Chapter 1, we discussed the melting and boiling of a substance. The heating curve for water is shown in Figure 1.11. For ice to melt to pro-duce liquid water, it must absorb energy from its surroundings. This energy is used to break down the weak forces between the water molecules (inter-molecular forces) in the ice. This energy is called the **enthalpy of fusion** and is given the symbol $\Delta H_{\mathbf{fusion}}$. Similarly, when liquid water changes into steam, the energy required for this process to occur is called the **enthalpy of vaporisation** and is given the symbol $\Delta H_{\mathbf{vap}}$. Figure 13.23 shows the energy level diagrams representing both the fusion and the vaporisation processes.

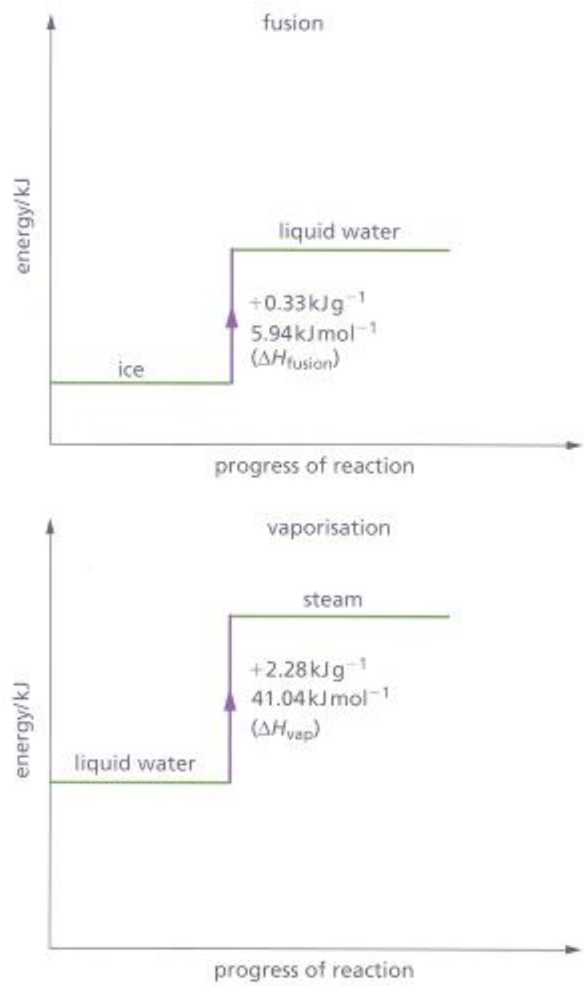


Figure 13.23 Energy level diagram for the fusion and vaporisation of water.

Questions

1. Describe the energy changes which take place when the processes described in this section, with water, are reversed.

2. Using the knowledge you have obtained from Chapter 1, give a full definition of the enthalpy of fusion and enthalpy of vaporisation for water.

Cells and batteries

A simple type of chemical cell is that shown in Figure 13.24a. In this cell the more reactive metal zinc dissolves in the dilute sulphuric acid, producing zinc ions ($Zn^{2+}(aq)$) and releasing two electrons.

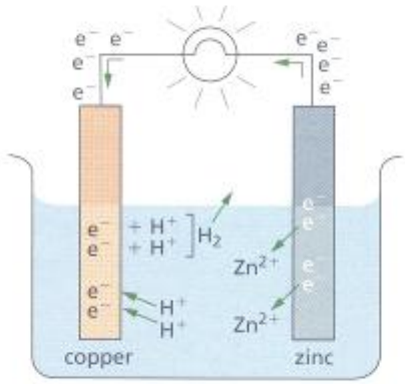
$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$$

The electrons produced at the zinc electrode flow through the external circuit via the bulb and the bulb glows. Bubbles of hydrogen are seen when the electrons arrive at the copper electrode. The hydrogen gas is produced from the hydrogen ions in the acid, which collect the electrons appearing at the copper electrode.

$$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$$

Slowly, the zinc electrode dissolves in the acid and the bulb will then go out. If the zinc is replaced by a more reactive metal, such as magnesium, then the bulb glows more brightly. Magnesium loses electrons more easily as it reacts faster with the dilute acid.

The difference in the reactivity between the two metals used in the cell creates a particular voltage reading on the voltmeter shown in Figure 13.24b. The more the two metals differ in reactivity, the larger is the voltage shown and delivered by the cell. This method can be used to confirm the order of reactivity of the metals (Chapter 9). Other types of chemical cell in common use are dry cells used in radios, torches, and so on, and lead-acid accumulators used in motor vehicles.



a A simple chemical cell.

b The voltage reflects the difference in reactivity of the metals.

Figure 13.24

Fuel cells

Scientists have found a much more efficient way of changing chemical energy into electrical energy, using a fuel cell (Figure 13.25). Fuel cells are like the chemical cells in the previous section, except that the reagents are supplied continuously to the electrodes. The reagents are usually hydrogen and oxygen. The fuel cell principle was first discovered by Sir William Grove in 1839.

When he was electrolysing water and he switched off the power supply, he noticed that a current still flowed but in the reverse direction. Subsequently, the process was explained in terms of the reactions at the electrodes' surfaces of the oxygen and hydrogen gases which had been produced during the electrolysis.

The hydrogen fuel cells used by NASA in the US space programme are about 70% efficient and, since the only product is water, they are pollution free. The aqueous NaOH electrolyte is kept within the cell by electrodes which are porous, allowing the transfer of O_2, H_2, and water through them (Figure 13.26). As O_2 gas is passed into the cathode region of the cell it is reduced:

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The OH^- ions formed are removed from the fuel cell by reaction with H_2:

$$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$$

The electrons produced by this process pass around an external circuit to the cathode.

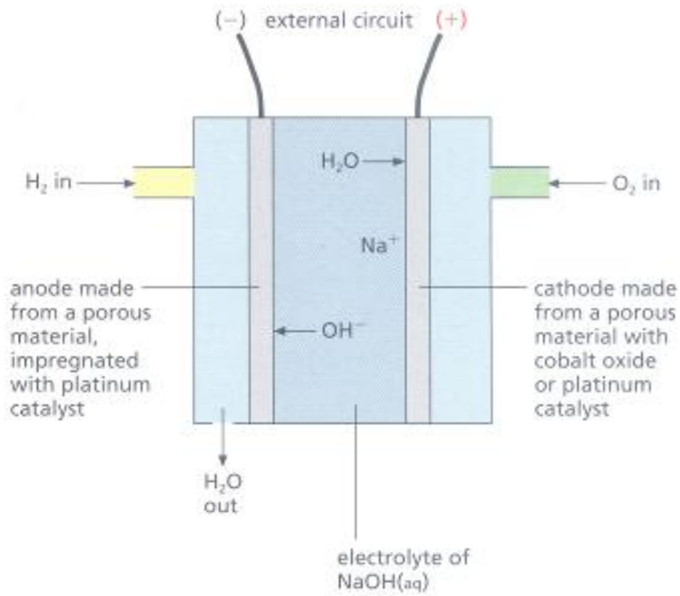


Figure 13.26 A diagrammatic view of a fuel cell.

Questions

1. Describe how simple chemical cells can be used to confirm the order of reactivity of the metals in the reactivity series.

2. The fuel cell was discovered during electrolysis experiments with water. It is the reverse process which produces the electricity. Write a balanced chemical equation to represent the overall reaction taking place in a fuel cell.

Figure 13.25 The space shuttle's computers use electricity produced by fuel cells.

Checklist

After studying Chapter 13 you should know and understand the following terms.

Aerobic decay Decay which takes place in the presence of oxygen.

Anaerobic decay Decay which takes place in the absence of oxygen.

Bond energy An amount of energy associated with a particular bond in a molecular element or compound.

Chain reaction A nuclear reaction which is self-sustaining as a result of one of the products causing further reactions.

Chemical cell A system for converting chemical energy to electrical energy.

Combustion A chemical reaction in which a substance reacts rapidly with oxygen with the production of heat and light.

Endothermic reaction A chemical reaction which absorbs heat energy from its surroundings.

Enthalpy Energy stored in chemical bonds, given the symbol H.

Enthalpy change Given the symbol ΔH, it represents the difference between energies of reactants and products.

Enthalpy of combustion The enthalpy change which takes place when one mole of a substance is completely burned in oxygen.

Enthalpy of fusion The enthalpy change that takes place when one mole of a solid is changed to one mole of liquid at the same temperature.

Enthalpy of neutralisation The enthalpy change which takes place when one mole of hydrogen ions is completely neutralised.

Enthalpy of vaporisation The enthalpy change that takes place when one mole of liquid is changed to one mole of vapour at the same temperature.

Exothermic reaction A chemical reaction that releases heat energy into its surroundings.

Fossil fuels Fuels, such as coal, oil and natural gas, formed from the remains of plants and animals.

Non-renewable energy sources Sources of energy, such as fossil fuels, which take millions of years to form and which we are using up at a rapid rate.

Nuclear fission The disintegration of a radioactive nucleus into two or more lighter fragments. The energy released in the process is called nuclear energy.

Renewable energy Sources of energy which cannot be used up or which can be made at a rate faster than the rate of use.

Energy sources

Additional questions

1a. State which of the following processes is endothermic and which is exothermic.

(i) The breaking of a chemical bond.

(ii) The forming of a chemical bond.

b. The table below shows the bond energy data for a series of covalent bonds.

(i) Use the information given in the table to calculate the overall enthalpy change for the combustion of ethanol producing carbon dioxide and water.

(ii) Is the process in (i) endothermic or exothermic?

Bond	**Bond energy/kJ mol^{-1}**
C–H	435
O=O	497
C=O	803
H–O	464
C–C	347
C–O	358

2. Explain the following.

a. Hydroelectric power is a relatively cheap source of electricity,

b. Geothermal energy is a non-polluting form of energy.

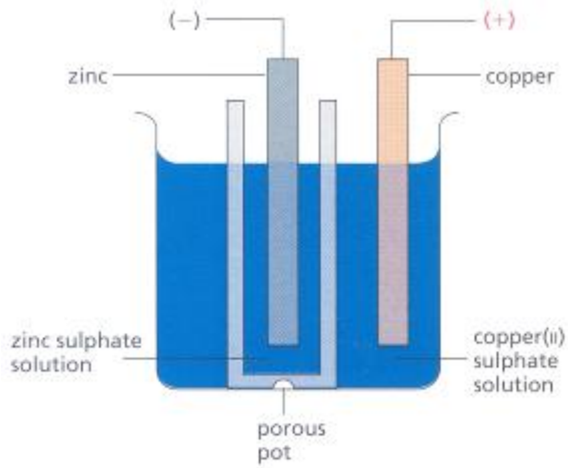
c. A disadvantage of wind power is that it causes noise pollution.

d. The by-product from the process by which methane is generated by the digestion of animal waste is an excellent fertiliser.

e. The fission of uranium-235 in a nuclear reactor is an example of a chain reaction.

f. Tidal- and wave-generated electricity has a major environmental disadvantage.

3. One of the first practical chemical cells was the Daniell cell invented by John Daniell in 1836. A diagram of this type of cell is shown below.



It is capable of generating about 1.1 volts and was used to operate small electrical items such as doorbells.

a. The electrode reaction taking place at a copper anode is:

$$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$$

Write an electrode equation for the process taking place at the cathode.

b. Which way would the electrons flow in the wire connected to the voltmeter - from 'copper to zinc' or 'zinc to copper'?

c. Why should copper (II) sulphate crystalise at the bottom of the outer container?

d. What is the function of the porous pot?

e. There are problems associated with the Daniell cell which has led to it being replaced by other types of cell. Give two reasons why Daniell cells are no longer in use today.

4. This question is about endothermic and exothermic reactions.

a. Explain the meaning of the terms endothermic and exothermic.

b. (i) Draw an energy level diagram for the reaction:

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta H = -57\ kJ\ mol^{-1}$$

(ii) Is this reaction endothermic or exothermic?

(iii) Calculate the energy change associated with this reaction if 2 moles of sodium hydroxide were neutralised by excess hydrochloric acid.

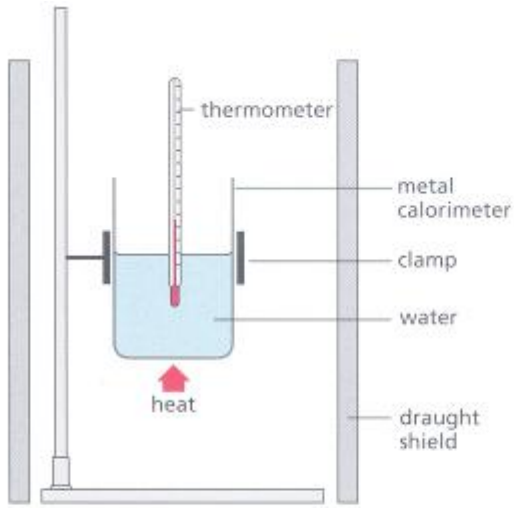
c. (i) Draw an energy level diagram for the reaction:

$$2H_2O(l) \rightarrow 2H_2(g) + O_2(g) \ \Delta H = +575\ kJ\ mol^{-1}$$

(ii) Is this reaction endothermic or exothermic?

(iii) Calculate the energy change for this reaction if only 9 g of water were converted into hydrogen and oxygen.

5.



The following results were obtained from an experiment carried out to measure the enthalpy of combustion (heat of combustion) of ethanol. The experiment involved heating a known volume of water with the flame from an ethanol burner. The burner was weighed initially and after the desired temperature rise had been obtained.

Volume of water in glass beaker = 200 cm^3
Mass of ethanol burner at start = 85.3 g
Mass of ethanol burner at end = 84.8 g
Temperature rise of water = 12°C

(Density of water = 1 g cm^{-3})

$$\begin{matrix}\text{Heat energy} \\ \text{given to water}\end{matrix} = \begin{matrix}\text{mass of} \\ \text{water/g}\end{matrix} \times 4.2\ \text{J g}^{-1}\ {}^\circ\text{C}^{-1} \times \text{temperature rise/}{}^\circ\text{C}$$

a. Calculate the mass of ethanol burned.

b. Calculate the amount of heat produced, in joules, in this experiment by the ethanol burning.

c. Convert your answer to b into kilojoules.

d. Calculate the amount of heat produced by 1 g of ethanol burning.

e. What is the mass of 1 mole of ethanol (C_2H_5OH)? (A_r: H = 1; C = 12; O = 16)

f. How much heat would be produced if 1 mole of ethanol had been burned? (This is the heat of combustion of ethanol.)

g. Compare your value with the actual value of 1371 kJ mol^{-1} and suggest two reasons for the difference in values.

h. Write a balanced chemical equation to represent the combustion of ethanol.

6. The following results were obtained from a neutralisation reaction between 1 moldm hydrochloric acid and 1 mol dm^{-3} sodium hydroxide. This experiment was carried out to measure the heat of neutralisation of hydrochloric acid. The temperature rise which occurred during the reaction was recorded.

Volume of sodium hydroxide used = 50 cm^3
Volume of acid used = 50 cm^3
Temperature rise = 5 °C

(Density of water =1 g cm^{-3})

$$\text{Heat energy given out during reaction} = \text{mass of water/g} \times 4.2\ J\ g^{-1}\ {}^{\circ}C^{-1} \times \text{temperature rise/}{}^{\circ}C$$

a. Write a balanced chemical equation for the reaction.

b. What mass of solution was warmed during the reaction?

c. How much heat energy was produced during the reaction?

d. How many moles of hydrochloric acid were involved in the reaction?

e. How much heat would be produced if 1 mole of hydrochloric acid had reacted? (This is the heat of neutralisation of hydrochloric acid.)

f. The heat of neutralisation of hydrochloric acid is -57 kJ mol^{-1}. Suggest two reasons why there is a difference between this and your calculated value.

7. Write down which factors are most important when deciding on a particular fuel for the purpose given:

a. fuel for a cigarette lighter

b. fuel for a camping stove

c. fuel for an aeroplane

d. fuel for an underground transport system

e. fuel for the space shuttle

f. fuel for domestic heating.

8. 'Propagas' is used in some central heating systems where natural gas is not available. It burns according to the following equation:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l) \quad \Delta H = -2220 \text{ kJ mol}^{-1}$$

a. What are the chemical names for 'propagas' and natural gas?

b. Would you expect the heat generated per mole of 'propagas' burned to be greater than that for natural gas? Explain your answer.

c. What is 'propagas' obtained from?

d. Calculate:

(i) the mass of 'propagas' required to produce 5550 kJ of energy

(ii) the heat energy produced by burning 0.5 mole of 'propagas'

(iii) the heat energy produced by burning 11 g of 'propagas'

(iv) the heat energy produced by burning 2000dm3 of 'propagas'.

(A_r: H = 1; C = 12; O = 16. One mole of any gas occupies 24 dm^3 at room temperature and pressure.)